NPK LUTS PROJECT OF CONTRABAND DETECTION SYSTEM

Yu.A. Svistunov, M.F. Vorogushin, Yu.N. Gavrish,
A.V. Sidorov, A.M. Fialkovski

Scientific Research Efremov Institute of Electrophysical Aparatus,
St.Petersburg, 189631 Russia

Abstract

The new principle of contraband detection system is proposed. Our approach employs the pulsed neutron source. The CDS employs rf linac to provide a beam of deuterons 1 or 3.5 MeV, which impinge upon a target giving birth pulsed neutron flow. Matrix detection system registers gamma radiation, which is appeared under interactions neutrons and nuclei of investigated object. Explosives are identified by gamma registration under inelastic scattering of fast neutrons on N, O, C nuclei. Fissions are identified by enhancing of total neutron yield and special change of neutron (and gamma) energy and temporal spectra. Secondary gamma radiation is registered during beam pulse just as between pulses. Such identification of explosives and fission has guarantee of high sensitivity and low level of false alarms. Deuteron accelerating with help 433 MHz RFQ and tandem RFQ plus APF-cavity is considered. Problem of optimal beam modulation is discussed too.

Introduction

NPK LUTS (Scientific Production Complex of Linear Accelerators and Cyclotrons) is Division of D.V. Efremov Scientific Research Institute of Electrophysical Apparatus. Contraband Detection Technological Complex (CDTC) is designed to detect explosives, fission materials and in future vegetable drugs. Conceptual scheme of CDTC is given on fig. 1. CDTC consists of rf linac to provide a beam deuterons with output energy up to 3.5 MeV, neutron producing target, matrix detection system, system of processing of information, biological shield's blocks. Accelerating system consists of 1 MeV 433 MHz RFQ and 433 MHz IH-resonator with drift-tubes and alternating phase focusing (APF) as second stage of acceleration from 1 MeV up to 3.5 MeV. Injection system of linac provides double-modulated beam with output normalized emittance $5 \cdot 10^{-7}$ rad·m. Duration of macropulses is 100 μsec, duration of micropulses is 1 μsec. Interval between micropulses and length of micropulse are determined by trade-off of detector's possibility to process of maximal information against necessity to detect delayed neutrons between pulses. Matrix detection system detects secondary gamma radiation. For explosives monitoring is used PFNA method – pulsed fast neutron analysis. Secondary gammas are result inelastic scattering of fast neutrons on N, O, C nuclei during beam pulses. N, O, C nuclei are main components of explosives. Intervals between pulses may be used to detect drugs with help short-lived isotope analysis. Fission are identified by detection and processing of energy's and temporal spectra. If investigated object includes fission total yield of neutrons is enhanced and high energy's neutrons are appeared during neutron pulse measurements. Delayed neutrons are detected pulse measurements under between. CDTC includes local biological shield. Distribution of shield's blocks along complex is optimized. Proposed principle of contraband detection system has Russian patent [1].

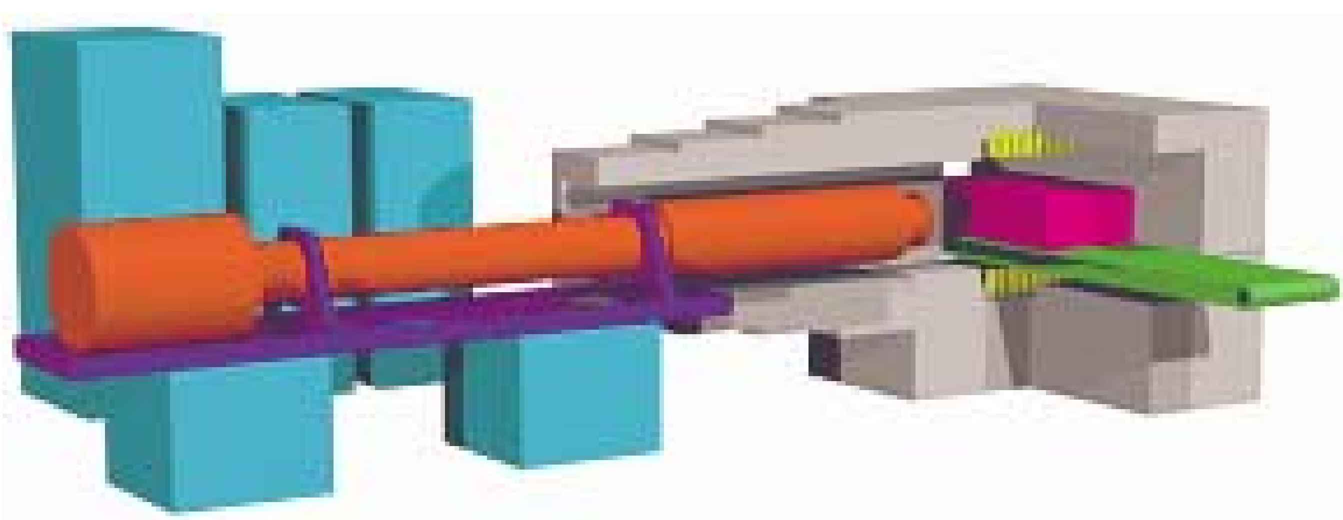


fig. 1. Conceptual scheme of contraband detection complex.

Accelerating system

Major components of rf linac are injector with deuteron plasma-surface source and system of beam forming and preacceleration; RFQ as first stage of acceleration, IH-resonator as second stage of acceleration, RF system, feeding system of injector and special extraction source system modulator. Special modulator provides dividing of a beam on macro and micropulses. RFQ provides acceleration of deuterons up to 1 MeV with output pulsed current 20 mA and beam emittance which may be matched with IH-resonator's acceptance. Construction of RFQ has eight main parts: four rigid flanges and four vanes. Length of vanes is 2.3 m. Direct material of constructive elements is chromium copper. . Mathematical modeling is shown [3] possibility to transport 20 mA deuteron beam with phase length after RFQ 0.6 rad via IH-resonator. It's effective length 0.9 m which correspond to 54 accelerating gaps. Main characteristics of linac are given in table 1.

Table 1. Main characteristics of accelerating system.

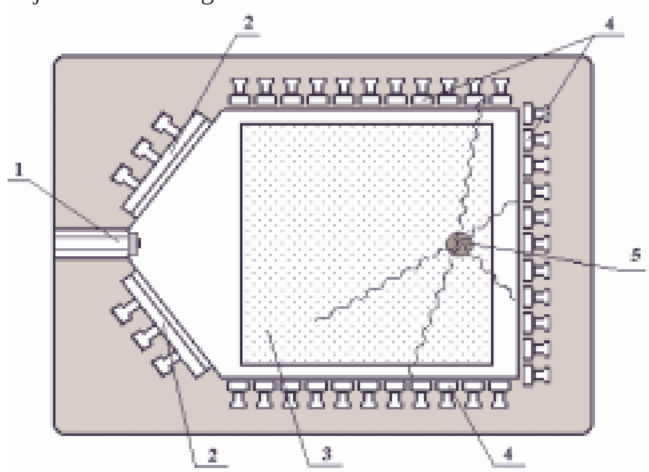
Characteristic	Type or value
Deuteron source type	plasma-surface
Extracting voltage	15-20 kV
Extracting pulse current	25 mA
Preaccelerating system type	electrostatic
Deuteron energy at RFQ input	60 keV
RFQ output energy	1 MeV
APF cavity output energy	3.5 MeV
Working frequency of resonators	433 MHz
Intervane voltage in RFQ	98 kV
Maximal electrical field's strength on z-axe of IH-resonator	120 kV/cm
Macropulse current duration	100μsec
Pulse repetition	up to 150 Hz
Pulsed power of output amplifier	400 kW
Length of rf power pulse	130 μsec
Output beam emittance (norm., theor.)	$1.5 \cdot 10^{-6}$ rad·m
Output energy spread (theor.)	± 1.4 %

Construction of NPK LUTS IH-resonators was described in principle in paper [2]. There were given results of testing of samples too. Only rf beam focusing is used in accelerating cavities therefore additional permanent magnetic focusing is absent. Enhance of deuteron energy on target from 1 to 3.5 MeV must increase neutron yield at least several times as much. For example, for beryllium target neutron yield will enhance on order.

Rf system consists of two amplifications lines with endotron type devices as power amplifiers or equivalent new klystron type devices by SED SPb. Stock Company. Principle of feeding of H-resonators (RFQ and IH-cavity) was written in paper [4].

Detection and processing systems

Yield and temporal distributions of neutrons and gamma radiation are measured by synchronous detector method. So long as neutron source is pulsed one and measures are produced under conditions of microstatistics this method gives the result. Detection system to detect explosives is scintillation counter matrix which is placed behind of investigated object and "looks over" it in full. Layout of detection system is shown on fig. 2. Each of matrix sell consists of CsI crystals with electron photomultiplier. Cell's sizes are 80×80 mm, number of cells may change from 32 (8×4) un pt 256. Enhance of number of detectors is necessary when big dimension objects are investigate.



Fig, 2, Layout of detection system.
1 – target device; 2 – fission monitoring; 3 – investigated object; 4 – explosive monitoring; 5 – location of fission or explosive inside investigated object.

Signals of detectors are transmitted into A/D converter via tract of signal amplification and normalization. Information is stored in on-line memory modulus and then processed by special code. This code provides selection and summation digital spectrometrical signals during neutron pulses just as between them. Maximal information are given by characteristic lines 2.31 MeV – for nitrogen, 4.44 MeV – for carbon, 6.31 MeV – for oxygen. These gammas gave maximal yield under target's irradiation by fast neutrons of continuous spectrum. As result of processing of energy's gamma spectra spatial and quantifiabled distributions N, O, C elements inside object are determinated. Elemental composition of the main types of explosives and some organic materials one can see from table 2.

Values of relative detector's signals under characteristic γ-radiation detection from N, O, C are given of fig. 3 as coordinates are used relations of separate element's concentrations to sum of concentrations of N, O, C. One can see the good separation explosives. This property is used for information processing. Detection system of fission consists of two effective detectors made with "fast plastic". Detector's signals are transmitted on summation via tract amplification and normalization and then on temporal analyzer. Start of analyzer is produced by synchronizing pulse from accelerator. After analyzer information is accessed into computer memory and processed by special code.

Table 2. Element composition of the main types of explosives and some organic materials

Substance	Formula	Mol. weight	N, %	O, %	Dens.g· cm^{-3}
Nitroglycerin	$C_3H_5O_9N_3$	227	18.5	63.4	1.47
Trinitrotoluene, TNT	$C_7H_5O_6N_3$	227	18.5	42.2	1.64
Tetryl	$C_7H_5O_8N_5$	287	24.4	44.5	1.73
Picric acid	$C_6H_3O_7N_3$	229	18.3	48.8	1.76
TEN	$C_5H_8O_{12}N_4$	316	17.8	60.8	1.77
Octogen	$C_4H_8O_8N_8$	296	37.8	43.3	1.96
Melamine	$C_3H_6N_6$	126	66.7	-	1.57
Polyurethane	polymer	$>10^4$	15.3	37.0	1.17-1.21
Polyamide fiber	polymer	$>10^4$	12.4	14.2	1.09-1.14
Polyacrilic fiber	polymer	>40000	25.4	-	1.15-1.17

Status

Now RFQ is manufactured just as modulators, detection system and other blocks. NPK LUTS has three devices of endotron type KIWI with maximal pulsed power 400 kW and working frequency 433 MHz. In future we proposed instead of KIWI devices to use a new power amplifiers which are manufactured by SED SPb Stock Company now. First sample of accelerating system with 1 MeV RFQ and power amplifies

KIWI will be tested on laboratory stand by H_2^+ ion beam in 2000, Sample of CDTC will be tested as it is proposed in the next year.

References

[1] M.F. Vorogushin, Yu.N. Gavrish, A.V. Sidorov, A.M. Fialkovski. Method of detection of explosives and fiddion. Russian patent № 2150105. Priority since May 26,1999 (in Russian).

[2] S.A. Minaev, Yu.A. Svistunov, S.A. Silaev. Modeling and Testing of APF Cavity RF Field. Proc. of Workshop BDO-95, St.Petersburg p. 130, 1996.

[3] Z.A. Andreeva, Yu.A. Zuev. Private communication 2000.

[4] M.F. Vorogushin, Yu.A. Svistunov. Key systems of an 433 MHz ion linac for applied purposes. Proc. of Conference Linac 96. Jeneva, August 26-30, V.2 p.866 (1996)

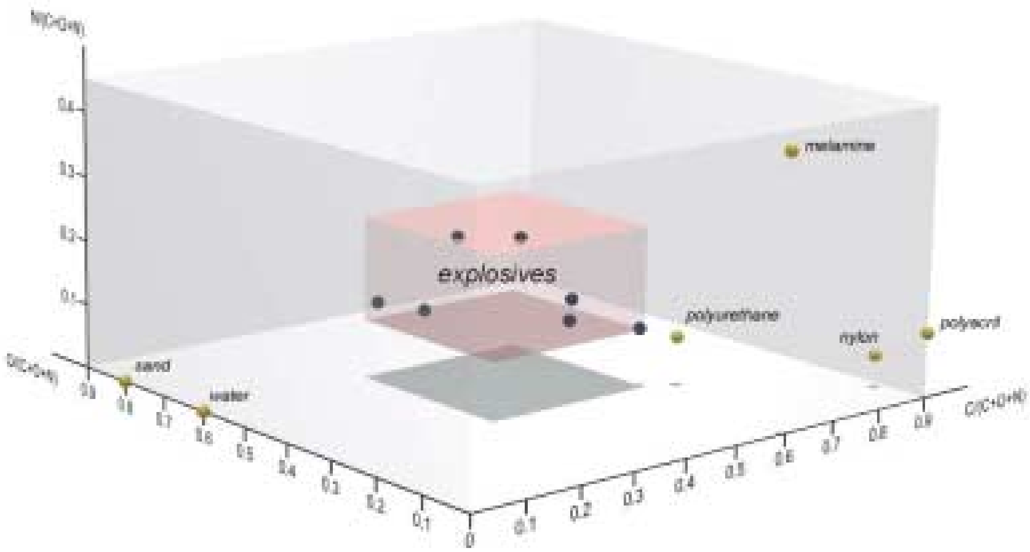


fig 3. Betweenness characteristic γ- radiations from N, O, C for explosives and other substances.